1.—Spilitic pillow lavas at Mt. Hunt, Western Australia

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Abstract

Spilitic pillow lavas form irregular zones within a sequence of unpillowed high-Mg basalts near Mt. Hunt, Western Australia. These pillows are strongly zoned, alkali-enriched and are petrologically and chemically distinct from the tholeiitic basalts which dominate Archaean volcanic belts throughout the Eastern Goldfields region. It is suggested that the spilitic pillows were derived from lavas similar in composition to the high-Mg basalts of the Mt. Hunt sequence.

Introduction

Mt. Hunt is 19 km south of Kalgoorlie, to the east of the Kalgoorlie-Kambalda road. Williams (1970) has established the Mt. Hunt sequence as the type area for the Mulgabbie Formation. He suggests a correlation of the Mt. Hunt sequence with a volcanic belt passing through the Corsair, Golden Ridge and Duplex Hill districts. The structure of the area is complex and interpretation is hampered by poor outcrop in critical areas. Essentially, the sequence consists of several belts of NNW-trending, west-facing basalt with intercalated bands of contorted jaspilite. A thick, conformable, west-facing layered sill and several semi-conformable masses of serpentized ultramafic have been intruded along sedimentary horizons. Discordant porphyry dykes are common and the sequence has been highly folded and faulted, and in places subjected to deep weathering and lateritization.

The massive basalt flows forming the bulk of the sequence are magnesium in nature (8% to 15% MgO) and show the various "quench" textures and skeletal crystal forms which typify this group of basalts throughout the Eastern Goldfields region. Within the stratigraphically older high-Mg basalt flows to the east of Mt. Hunt are several highly altered variolitic horizons and patchy zones where pillows are developed. The best exposure of these pillow lavas is in a small creek bed, 450 m due east of the Mt. Hunt trig point (Figure 1). The pillows range from 0.5 m to 2.5 m in length, and are moderately flattened in the plane of bedding. They are concentrically zoned with mottled greenish cores showing irregular fractures and variolitic margins with closely spaced joints perpendicular to the pillow outline. Dense chilled skins up to 5 cm in thickness surround the pillows. The matrix in which the pillows are set appears to have been a peperite of glassy pillow fragments with some sedimentary material.

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Petrology

Chilled pillow skins are formed of a dense, felted, fine-grained mixture of chlorite, tremolite and clinozoisite. Variolitic pillow margins consist of numerous spherical varioles up to 1 cm in diameter set in a dusted mesostasis of chlorite, clinozoisite, albite and tremolite. The outlines of scattered pyroxene phenocrysts which have been replaced by uralite can occasionally be seen. The varioles contain radiating sheaves of partially saussiritized plagioclase (An_5) intergrown with elongate needles of uralitized pyroxene. A thin selvedge of granular pyroxenes replaced by uralite commonly surrounds the varioles. Pillow cores are filled with up to 65% ragged, randomly oriented lathes of plagioclase (An_{5-25}) in a groundmass of chlorite, clinozoisite, tremolite and fine-grained opaques. The plagioclase lathes are water-clear and well twinned.

The mineralogy of these pillows differs markedly from that of tholeiitic pillows throughout the Eastern Goldfields, which are invariably composed of a pleochroic green amphibole and plagioclase with only trace amounts of chlorite, epidote, clinozoisite and quartz (Hallberg, 1971). The composition of the plagioclase in the pillows at Mt. Hunt is more sodic than that in the normal tholeiitic pillows, which contain either a primary labradorite or andesine or a metamorphic oligoclase. There is no indication that the pillows at Mt. Hunt have undergone recrystallization during low-grade regional metamorphism.

Analytical Data

Fresh samples of the core, margin and matrix of a well-formed pillow in the creek bed exposure were subjected to major and trace element analysis (Table 1). Results indicate that the pillow becomes enriched in Si and Na and depleted in K, Rb, Mg and Fe towards its core; the entire pillow is enriched in volatiles. Ti, Al and most of the less mobile trace elements show little variation across the pillow. This zonation contrasts with the more uniform distribution shown by most tholeiitic pillows in the Eastern Goldfields (Hallberg, 1971). The Mt. Hunt pillow is also enriched in alkalis and volatiles with respect to the tholeiites as shown in Table 1. Perhaps the most unusual feature of the pillow is its high Cr and Ni contents which contrast with previously reported values for both tholeiites and spilites.

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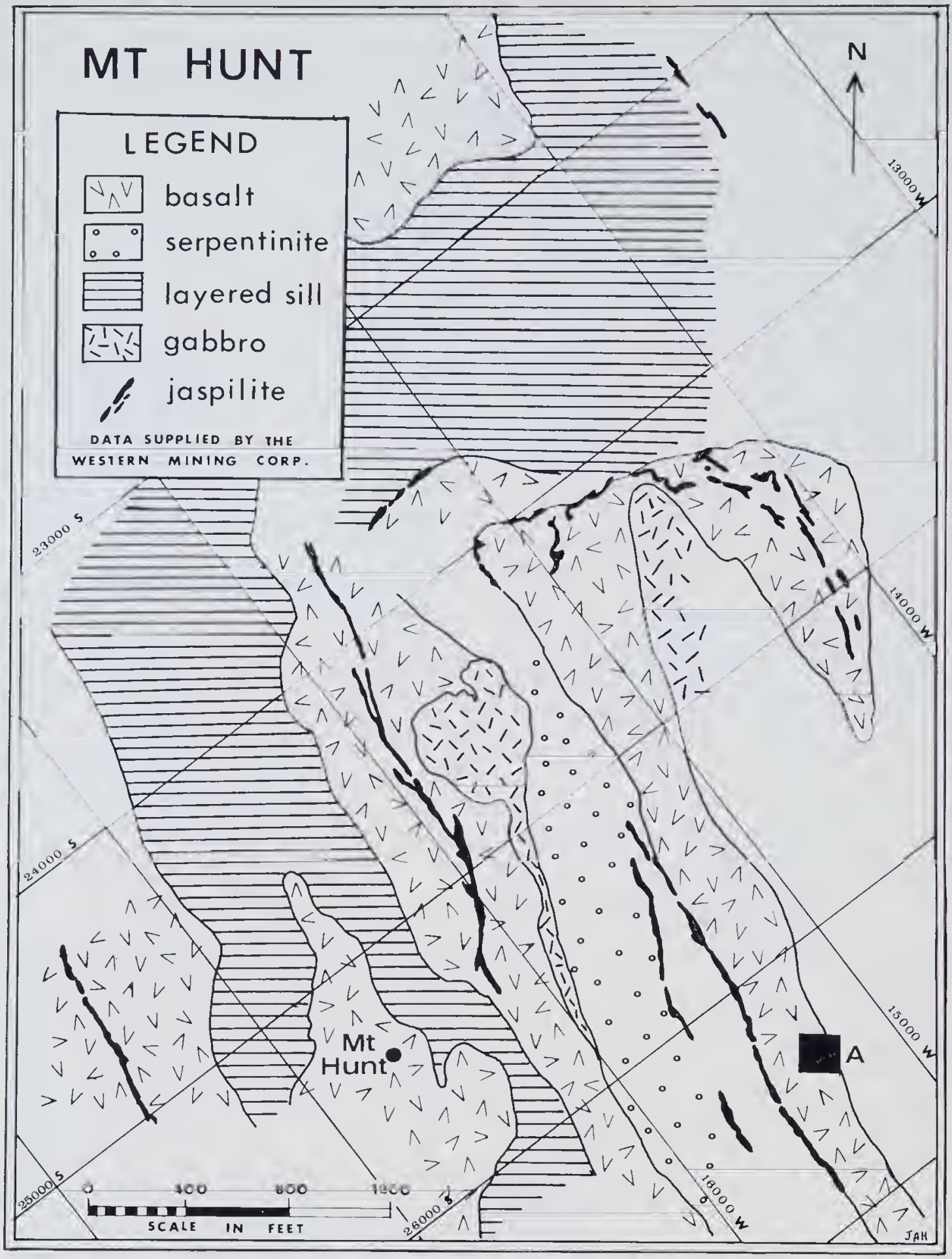

Figure 1.—Geological map of Mt. Hunt and vicinity. Area "A" is the creek-bed exposure of spilitic pillow lavas.

TABLE 1

Analysis of spilitic pillow lavas from Mt. Hunt

	1	2	3	4	5	6	7
SiO_2	46.25	54.48	57.10	51.4	52.81	49.6	48.33
Al_2O_3	16.12	14.25	16.85	14.8	13.42	16.0	15.44
Fe_2O_3	2.51	2.29	2.48	1.5	2.27	3.8	
FeO	9.45	7.75	3.76	9.1	7.40	6.1	8.58*
MgO	9.96	8.07	4.35	6.7	9.81	5.1	7.41
CaO	7.63	6.99	6.77	10.7	9.12	6.6	8.02
Na_2O	0.67	0.93	5.12	2.7	1.94	4.3	4.96
K_2O	1.54	1.03	0.06	0.18	0.43	1.28	0.72
H_2O+	3.72	2.98	1.92	1.0	1.79	3.4	
H_2O-	0.41	0.19	0.69		0.25		
CO_2	0.33	0.35	0.10	0.1	0.25	1.63	
TiO_2	0.77	0.75	0.74	0.92	0.60	1.57	0.59
P_2O_5	0.11	0.08	0.08	0.13	0.12	0.26	
MnO	0.28	0.23	0.14	0.21	0.16	0.15	
Total	99.75	100.47	100.16				
Co	90	71	59	59	65		
Cr	817	891	841	395	901		
Cu	103	97	82	98	67		
Ni	285	222	280	161	243		
Rb	66	41	4	9	8		
Sr	90	95	92	105	176		
Y	37	33	22	22	17		
Zn	176	138	99	112	71		
Zr	68	66	67	60	71		
Q	—	14.2	6.9	0.8	5.3		
or	9.5	6.3	0.3	1.0	2.6		
ab	5.9	8.1	44.5	23.5	16.4		
an	38.1	32.8	23.4	28.0	27.3		
di wo	0.3	1.0	4.3	10.4	7.5		
di en	0.2	0.6	2.9	5.4	4.8		
di fs	0.1	0.3	1.0	4.6	2.2		
hy en	23.6	20.1	8.1	11.6	19.8		
hy fs	13.8	11.6	2.9	9.9	9.1		
ol fo	1.5	—	—	—	—		
ol fa	0.9	—	—	—	—		
mt	3.8	3.4	3.7	2.2	3.2		
il	1.5	1.4	1.4	1.7	1.1		
ap	0.2	0.2	0.2	0.3	0.2		

1 — matrix, spilitic pillow, Mt. Hunt, W.A.
2 — margin, spilitic pillow, Mt. Hunt, W.A.
3 — core, spilitic pillow, Mt. Hunt, W.A.
4 — average Eastern Goldfields tholeiitic basalt (Hallberg, 1971).
5 — average of five high-Mg basalts, Mt. Hunt, W.A.
6 — average spilite (Valance, 1960).
7 — average of 53 spilites, Virgin Islands (Hekinian, 1971).

CIPW norms calculated on a volatile-free basis.

* Total Fe as FeO.

Affinities

In morphology, mineralogy and chemistry the Mt. Hunt pillows are similar to reported spilites. Vallance (1960, p. 22) notes that "Variolitic textures are common in many spilites . . .", and that "Amygdules and veins appear in almost all recorded spilites but unfilled cavities, on the other hand, are rare.". Bailey *et al.* (1964) describe similar pillows from the Franciscan Formation of California and Hekinian (1971), highly variolitic pillows from the U.S. Virgin Islands. Amstutz (1967) and Hekinian (1971) list albite, chlorite, epidote, calcite and iron oxides as the major constituents of volcanic spilites. Spilites may contain a calcic augite or salite. Vallance (1960) maintains that the only distinguishing chemical characteristic of spilites is their high volatile content. In this respect it should be noted that the volatile content of the Mt. Hunt pillow is much greater than that of the average Coolgardie-Norseman basalt (Table 1). Spilites also tend to be enriched in alkalis (Amstutz, 1967). Chemically, the pillow from Mt. Hunt compares closely with spilite analyses reported by Vallance (1960) and Hekinian (1971), as shown in Table 1, and with pillows from the Franciscan Formation (Bailey *et al.*, 1964), as shown in Figure 2. On the basis of these similarities it is concluded that the pillowed units at Mt. Hunt represent true spilites.

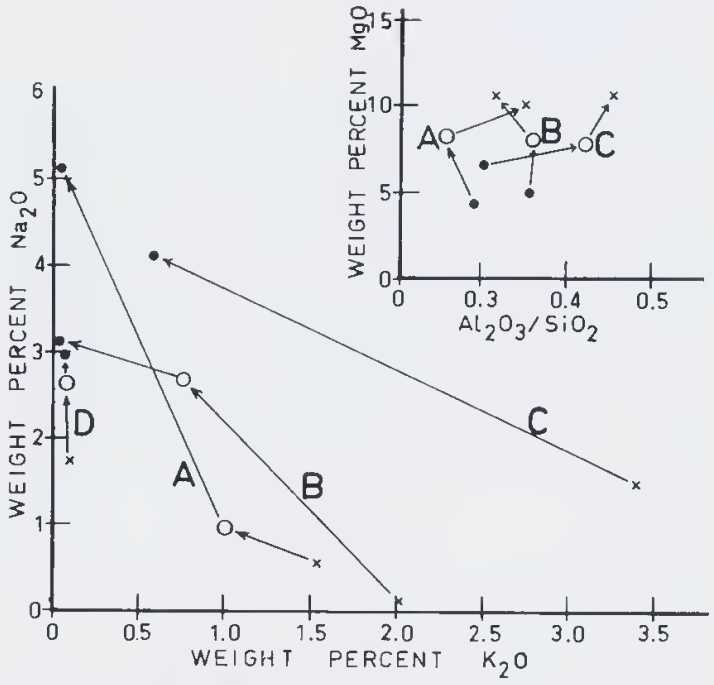

Figure 2.—Major oxide variations in spilitic pillow, Mt. Hunt. A = spilitic pillow, Mt. Hunt, B and C = spilitic pillows from the Franciscan Formation of California (Bailey *et al.* 1964), D = tholeiitic pillow, Norseman, W.A. (Hallberg, 1970). Solid circles indicate pillow cores, open circles pillow margins and x's pillow matrices.

Discussion

Archaean spilites have been reported from Sweden and India (Valance, 1960) and from South America (Williams *et al.*, 1967). Although Archaean "greenstones" from Western Australia have been collectively referred to as spilites (Prider, 1948, 1961), this usage follows the assumption that all metamorphosed Archaean pillowed basalts are spilites, a supposition which is certainly not true for examples from Western Australia (Hallberg, 1970). The Mt. Hunt pillows may represent an isolated case of spilite development; a regional investigation of Archaean volcanic belts has disclosed no similar occurrence (Hallberg, 1970).

Spilitic magmas, autometasomatism, reaction with sea water and post-consolidation alteration have been proposed as mechanisms for producing spilites (Vallance, 1960). Some indication of the nature of the magma from which the spilites at Mt. Hunt were derived is given by their high concentration of Cr, Ni and Mg. It is unlikely that Cr and Ni could have been added to the pillows by any of the mechanisms mentioned; it can therefore be concluded that these values reflect the composition of the melt from which the pillows formed. The Cr and Ni values for the spilitic pillows are identical to those in the associated high-Mg basalts (Table 1). It is therefore postulated that the pillows were

formed from a high-Mg basalt magma and that spilitization occurred during or after pillow formation. The association of high-Mg basalts, layered sills, intrusive ultramafics and pelitic sediments is believed to represent a sequence of oceanic crustal material (Hallberg and Williams, unpublished data). That spilites can develop in such an environment is attested to by their presence in some Alpine sequences (Vallance, 1960). Perhaps the most important, and yet unanswered, question is why similar spilitic rocks have not developed in other volcanic belts in the Eastern Goldfields region deposited in similar environments.

Acknowledgements

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